

A New Type of Rotor + Airbag Hybrid Unmanned Aerial Vehicle

Yun Wang^{*1}, Shuling Le², Zhiwu Fan³

School of Aircraft Engineering, Nanchang Hangkong University, Nanchang, Jiangxi, 330063, China

^{*1}wangyun66@126.com; ²leshuling1022@163.com; ³1459409014@qq.com

Abstract

A presentation of a hybrid Unmanned Aerial Vehicle(UAV) overall scheme is put forward according to current technology coping with the difficulties in the field of Airborne Geophysical Prospecting(AGP) and the flight environment of ground layer. On the base of this concept, the preliminary results of the prototype parameters are given, showing a new idea for the low-altitude and low-speed aircraft. In addition, the feasibility and economic of aircraft have been investigated by means of the analysis on the aircraft advantages and key technologies.

Keywords

Rotor; Airbag; Unmanned Aerial Vehicle(UAV); Overall Scheme

Introduction

Airborne Geophysical Prospecting(AGP), equipped with detection instruments on aircraft(such as fixed-wing aircraft, helicopter, etc.), is a kind of flight activity which can detect the subsurface geology and mineral resources by measuring the changes of earth physical field from low-altitude^[1]. However, AGP is limited in the aircraft performance and flight personnel, and in some areas, it is difficult for aircrafts to keep low-flying height.

At present, Unmanned Aerial Vehicles(UAVS) applied to the field of AGP are rare. In recent years, with the development of technologies, the application and research on quad-rotor UAV and airship are drawn more and more attention. Compared to fixed-wing aircraft and single rotor helicopter, quad-rotor UAV has many advantages, like strong flexibility, high energy utilization rate, well-designed structure, high security, etc, but with some shortcomings, such as small payload, short time of endurance, weak anti-interference ability, and so on; while in comparison with other aircrafts, airships have the advantages of strong load capacity, low noise, low energy wastage and high security, etc.

According to AGP technical difficulties and aircraft characteristics, new aircraft program in combination with multirotor technology and principle of the balloon is put forward, along with the investigation on heavy load, efficiency, stability, security, convenience, low-cost UAV in this paper.

Flight Environment Analysis

The flight range of UAV is in the ground layer from sea-level location to 100 meters, belonging to the lower layer of the troposphere. In this layer, with the increase in height, the temperature decreases (about 0.65°C/100 m), and the air density changes slightly. However, because of the strong effects of the air-ground friction, turbulent exchange interaction is very strong, and generally, the wind speed increases and the orientation of the wind deflects with increasing height. The wind has great effect on UAV flight in this layer. Fig. 1 shows the average wind speed in December in various regions of China, the same as other months, and the monthly average wind speed is mainly 1~5 m/s.

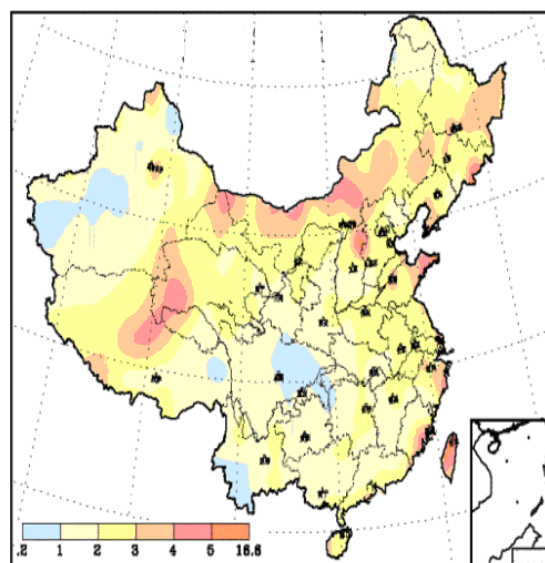


FIG.1 AVERAGE WIND SPEED IN DECEMBER IN CHINA

[1]: C

Overall Conceptual Design Of Hybrid UAV

System Composition and Function

Hybrid UAV includes structures and mechanisms, the flight control system, power and propulsion systems and payload compartment, and so on. Presented with energy and power from battery, the UAV can arrive in the way of vertical takeoff and landing, fixed-point hovering and level flight. The buoyancy of the airbag provides most flight lift, so the power consumption of quad-rotor can be reduced greatly, meanwhile, the payload of UAV can be increased, and with the same energy, UAV can fly longer. The UAV can adjust the flight attitude by means of changing rotors speed, as well as the flight directions and improving the wind-resistance, resulting from the level flight power provided by thrust propellers. The maneuverability of the UAV can be improved with the use of thrust propellers and quad-rotor together. The UAV structures are shown in Fig. 2.

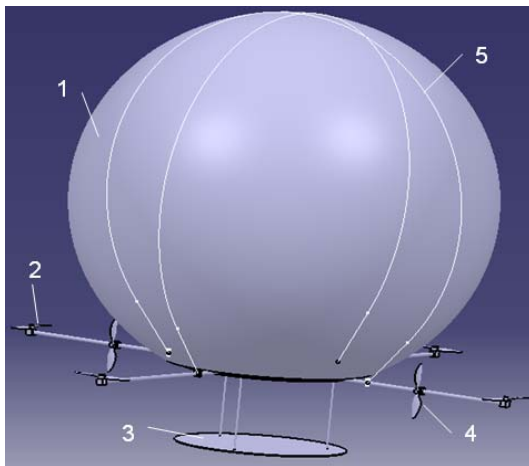


FIG.2 THE UAV STRUCTURES

- 1.Airbag; 2.Quad-rotor; 3.Payload compartment;
4.Thrust propellers; 5.Airbag

Flight Principles and Ways of Working

The hybrid UAV is a kind of aircraft relying on static lift and fan lift to achieve takeoff and hovering with propulsion system. The UAV ascends to the low altitude to execute tasks by means of hybrid lift, and keeps working gestures through the ground remote-control. Finally, it returns to the ground by its own gravity. During the entire work, UAV mainly has four processes: vertical takeoff and landing, climb, level flight and attitude adjustment. In the process of takeoff and climbing, the lift provided by airbag and quad-rotor can help UAV to get the hovering height,

and when the rotors speed of different position has changed, UAV can meet the rising speed requirements; while in the course of the level flight process, thrust propellers offer driving force, and the airbag and quad-rotor supply the hovering lift only; in addition, when landing, the total lift is less than UAV weight by reducing the rotors' speed, to make it land. When crosswind coming, in order to get the safe tilt angle, the rotors speed of No.1 and 2 increase, and that of No.3 and 4 decrease slightly, simultaneously, the speed of No.5 and 6 thrust propellers are adjusted to change the flight direction, so that UAV can be kept flying forwardly and the horizontal position can't change greatly. Which is shown in Fig. 3.

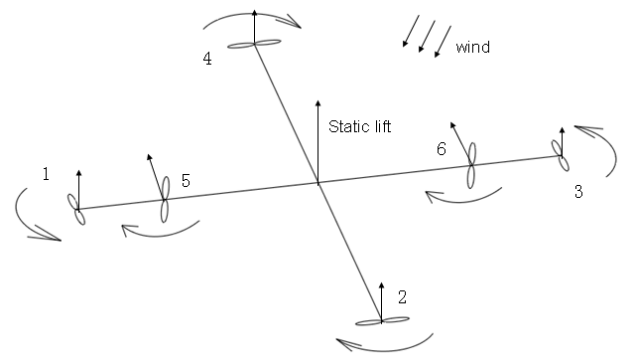


FIG.3 WORKING PRINCIPLE IN CROSSWIND

Calculations of Prototype Paramet-Ers

In this section, the prototype is designed on the base of the overall concept, to illustrate the feasibility of hybrid UAV. During the overall design, the flight speed of this prototype is 2 m/s, the time of endurance is about 28 min and the payload is 5~6 kg.

Takeoff Weight Estimating

Takeoff weight (W_0) is the basic parameter of the UAV, which determines the structure and size of airbag and rotors, including: empty weight (W_e), battery weight (W_b) and payload (W_p), that:

$$W_0 = W_e + W_b + W_p \quad (1)$$

Empty weight coefficient is $k_1 = W_e / W_0$, and battery weight coefficient is $k_2 = W_b / W_0$, so formula (1) can be adapted to:

$$W_0 = W_p / (1 - k_1 - k_2) \quad (2)$$

Presently, rotorcrafts mostly are small or light, the weight ratio(the ratio of empty weight and total

weight) of which is about 0.6^[2], but this prototype is different from the rotary-wing aircraft. According to the weight distribution of electric helicopter^[3], the ratio k_1 is 0.4. According to the weight parameters and usage of batteries, the coefficient k_2 is about 0.25^[4]. Finally, the takeoff weight (W_0) is about 16 kg.

Material and Dimensions of Airbag

The shape of the airbag is similar to a ball, and the lift is about 10 kg, so the airbag diameter is 2.5 m. In addition to the process and leak rate of the material, the tensile strength should be greater than the maximum ring tension caused by overpressure, and the formulas^[5] are as follows:

$$\sigma_{\max} = 0.5q_f R \quad (3)$$

$$q_f = (\rho_A - \rho_H) g R \quad (4)$$

Where,

$\sigma_{\max}$: the maximum ring tension of the airbag, N/m

q_f : overpressure, Pa

ρ_A : the air density at corresponding height, kg/m³

ρ_H : the helium density at corresponding height, kg/m³

R : airbag radius, m

Because the changes of air and helium density with the height are small, the overpressure changes slightly. The calculation results show that the maximum ring tension is approximately 8 N/m, and decreases with the increasing height. Above all, the requirements of airbag material are reduced, so the polyethylene or polyester film can be used for airbag materials, the surface density of which is 0.05~0.08 kg/m², and the cost is low.

Energy and Power Configuration

The energy and momentum of the prototype should be reasonable during the model design. According to the above-mentioned parameters, the selected results of energy and power devices are shown in Table 1.

Weight Distribution

According to preliminary calculation results and selected parts weight, the calculation on the weight of each prototype system is more accurate, the results of which are some different with the preliminary estimates. The results are shown in Fig. 4.

TABLE 1 ENERGY AND POWER DEVICES

	Quad-rotor system	Thrust system
Brushless motor	AS-4526 KV380	AS-4526 KV380
Brushless ESC	40 A	40 A
Propeller	APC 14×47	APC 14×47
Lithium battery	6S 15000 mAh 15 C	6S 10000 mAh 20 C

Advantages Analysis of Hybrid UAV

Compared with the quad-rotor aircraft, the power consumption of the rotors reduces significantly. Under the same energy, the UAV can fly longer and its payload increases. While compared to the traditional aircrafts used to AGP, the hybrid UAV holds many advantages.

Simple Structure and Low Manufacturing Cost

Generally, the main reason for the high cost of helicopters is that they require high-power engines, and complex transmission systems. The manufacturing cycle of light civilian helicopters is relatively short, but usually takes 3~5 years. The development cost of IS-2 Solely developed by PZL Swidnik company is about \$ 3.5 million, which is two-seater light civilian helicopter. On the contrary, the hybrid UAV excludes complex fuselage structure, drive mechanism and engine systems, resulting in simpler manufacturing process and shorter production cycle. The cost of airbag material, energy, power system can be at the low range, because the UAV flies at low speed and low-altitude. According to the target that the maximum takeoff weight of light civilian helicopter is about 1 ton, the airbag diameter is approximately 12 m. The material cost of the airbag values 40% of the airship skin, the cost of which is

1000 RMB/m²^[6], so the whole cost of airbag is about RMB 190,000. In addition, the helium cost is RMB 130,000, along with the cost of control system and power system and other, making the total cost expected to be not more than RMB 500,000 (about \$ 80,500), which is tenths of the cost of the light civilian helicopter. As stated above, the cost reduces greatly.

[2]: Q

[3]: Z

[4]: Y

[5]: Z, Y

[6]: Z, N

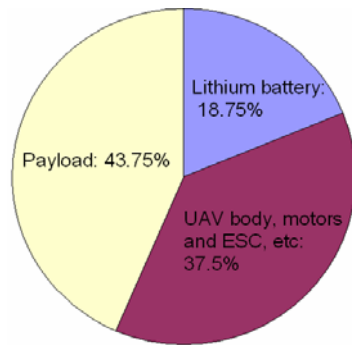


FIG. 4 WEIGHT DISTRIBUTION

Achieving the Low Flying Height and Improving the Detection Accuracy

When detecting the magnetite, the actual flight height is 50~150 m; while seeking the uranium, the height is 30~100 m. During the actual flight height, APG is limited with aircraft performance, and has difficulty in some areas. However, the flight path of UAV can be effectively controlled by the static lift and the rotor power, so that the UAV can hover, fly, climb and land at any height. Thereby, the detection accuracy is enhanced.

Improving Safety

Flight safety is the foundation of APG. In order to ensure the detection accuracy, the height should be reduced, which means that potential risk may go up. Conversely, the safety factor of UAV is higher, because it is unmanned and remoted on the ground.

Decreasing the Environmental Pollution

The theme "Cooperation and Innovation—building the green aviation industry chain" shows that the realization of "green aviation" should be the result of reduction on noise and decrement in consumption on the meeting of "the Sixth China International Aviation and Aerospace Forum". This kind of aircraft is beneficial to environmental protection by means of electric energy and the application of solar technology on the UAV.

Wide Application

In addition to APG field, the UAV can be applied to aerial observations, forestry operations, material transport and earthquake rescue, etc. The application prospect is promising.

The Key Technologies of the Hybrid UAV

The key technologies of the hybrid UAV includes the

following points:

1. The design of the rigid structure on the light quality airbag;
2. Dynamic energy technologies of long-endurance flight;
3. The research of the attitude adjustment system and wind resistance;
4. The ground guarantee technology of air inflation, maintenance, etc.

Conclusions

The hybrid UAV has advantages in many aspects, the research of which impels the APG development in a sense. In the future, many details of the UAV are the focus, such as the construction of technical simulation platform, local structure optimization, flight performance research, aerodynamic performance research, and so on.

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REFERENCES

- G-P. Chen. "'Airborne Geophysical Prospecting': Aerial prospecting master." China Finance, February 13, 2012. Accessed March 03, 2013.
<http://finance.china.com.cn/roll/20120213/529424.shtml>.
- H-F. Tan, S-H. Meng, C. Wang. "A New Type Deployable Airship." Chinese Aerostat Conference, 2007.
- Q-H. Zhu, J-B. Li, X-P. Ni, C-L. Zhang. "Several Aspects of Gyroplane Design." Aviation Science and Technology, No.5, pp. 28-32, 2006.
- Y. Zhang. "Integral Design and Research of the Tilt-Ducted Fan UAV." Nanchang Hangkong University, 2012.
- Z. Nie, M. Chen. "Calculation and Analysis of Electric-powered Helicopter Flight Performance." Journal of Beijing University of Aeronautics and Astronautics,

Vol.38, No.9, pp.1139-1143, Sep. 2012

Z-Y. Yu, Y-Y. Li. "A New Type of Stratospheric Dynamic Balloon." Chinese Aerostat Conference, 2007.

Yun Wang was born in Jiangxi Province, China, in 1966. He obtained Bachelor's degree in aircraft engine from Beihang University, Beijing, in 1987, and then received Master and Doctor Degree in aircraft engine from School of Aeronautics and Astronautics, Nanjing University of Aeronautics and Astronautics, Nanjing, during the time from 2001 to 2006. He worked in Helicopter Design Institute of China from 1987 to 1992, and since 1992, he has engaged in the research and teaching in the fields of technology and engineering, aircraft design and mechanical design aerospace propulsion in Nanchang Hangkong University, who is a professor now. He is the first author of more than thirty academic papers, four out of which are indexed by EI, meanwhile, he has received support of the National Fund, Aviation Fund and held some enterprise research projects. He has possessed one

national invention patent, four utility model patents and two opened invention patents. He was honored with the second award of the Science and Technology Achievement by Jiangxi Provincial Department of Education, in addition, he has edited and published three textbooks.

Shuling Le was born in Jiangxi Province, China, in 1985. She received Bachelor's Degree in process equipment and control engineering from School of Environmental Science and Engineering, Nanchang University, Nanchang, Jiangxi, in 2008. And then, she worked in Nanchang Gear Forging Factory from 2008 to 2010. Currently, she is pursuing the Master's degree in overall design of flight vehicle, Nanchang Hangkong University, Nanchang, Jiangxi. Her research interests are overall design and numerical simulation.

Zhiwu Fan was born in Jiangxi Province, China, in 1991. He is pursuing the Bachelor's Degree in Aircraft design and engineering, Nanchang Hangkong University, Nanchang, Jiangxi.